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Status of solar wind renewable energy in India

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ABSTRACT

There are some specific constraints that hinder the development of solar and wind energy system in India. However, India has adequate sunshine and balanced wind speed. Hence there is greater opportunity for extension of solar and wind energy system in the Indian scenario along with enough future scope for these renewable sources through "Grid Parity". The aim of this paper is to present in a coherent and integrated way the major constraints hampering the development of renewable energy in India.

Contents

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1. Introduction

Electricity is the key factor for industrialization, urbanization, economic growth and improvement of quality of life in society. India is the world's fifth prevalent in the electricity sector. India has an installed capacity of 207.85 GW as on September 2012. Captive power plant generates further 31.5 GW. India's foremost transmission producer POWERGRID owns 79,556 circuit km of transmission line and 132 substations that are found in one of India's five transmission areas, that is, Eastern region, Western region, Northern region, North Eastern region, Southern region. Regional load dispatch center (RLDC) is a region house that organizes the use of the transmission system among these regions. State load dispatch center (SLDC) organizes transmission usage within the state and reports this datum to its overseeing RLDC [1]. Distribution amenities provide electricity to 144 million customers in India. These amenities incorporate step down substations and lines to carry the electricity at lower voltages to the electricity consumer. In stipulations of fuel coal fired power plant for 56% of India's installed capacity, hydropower accounts for 19%, natural gas 9% and renewable energy produces 12%. Depletion of conventional resources forces countries to develop effective strategies on energy mix. This requires a novel normative approach in planning for and supporting research on different energy resources. The International Energy Agency (IEA) estimates India needs an asset of at least 135 billion US dollars to give universal access to electricity to its population. According to IEA India will append between 600 GW and 1200 GW of supplementary new power generation capacity before 2050. Over 2010–11 India's industrial demand accounted for 35% of electrical power need, domestic household use 21%, agriculture 21%, commercial 9% and miscellaneous application accounted for the rest according to the 17th electric power survey of India [1,2].

- The electrical energy demand for 2016–17 is anticipated to be at least 1392 TWh, with a peak electric demand of 218 GW.
- The electrical energy demand for 2021–22 is anticipated to be at least 1915 TWh, with a peak electric demand of 298 GW [1,2].

To move to this state of affairs the Indian Government endorses renewable energy sources. These energy sources may deal with restraint about fuel flexibility, efficiency, reliability, economics and emission. The energy mix should revolutionize and start further renewable energy sources (RES) to diminish power generation pollution as well as greater balance in energy supply [6]. India's electricity sector is among the world's most active players in renewable energy utilization. As of December 2011, India produces 22.4 GW electricity based on renewable technology that is beyond the total installed electricity in Austria by all technologies. India was the first country in the world to set up a Ministry of non-conventional energy resources in early 1980 [1,2]. Wind and solar energy are omnipresent, freely available, and environment friendly. The wind energy systems may not be technically viable at all sites because of low wind speeds and being more unpredictable than solar energy. The combined utilization of these renewable energy sources is therefore becoming increasingly attractive and is being widely used as an alternative for oil-produced energy [7]. With these considerations the aim of this paper is to describe in an onslaught and integrated way the major constraint hindering the development of renewable energy in India. Table 1 represents the electricity sector capacity and availability in India.

2. Solar energy in India

2.1. Overview

Sunlight can be converted directly into electricity using photovoltaic (PV). The photovoltaic generation is a technique of converting solar radiation or photon energy into direct current electricity using a semiconductor material that exhibits photovoltaic effect. The International Energy Agency has numerated photovoltaic applications into four categories, namely, off-grid domestic, off-grid nondomestic, grid connected distributed, and grid connected centralized [8]. A typical PV module is made up of around 36 or 72 cells connected in series, encapsulated in a structure made of aluminum, depending on the application and type of cell technology being used [9]. The dominance of photovoltaic (PV) among renewable energy technologies is owed mostly to its noiselessness, non-toxic emission, and relatively simple operation and maintenance [14]. The increasing demand of electricity peak load has activated the utilization of renewable energy for different kinds of applications, such as heating, ventilation, and air-conditioning (HVAC) areas. Researchers also find the potential application of solar energy in cold storage system and utilization of thermal and physicochemical properties of different phase change materials in photovoltaic system [3–5]. These are important and relatively inexpensive sources of electrical energy where grid power is inconvenient, unreasonably expensive to connect, or

Table 1
Electricity sector capacity and availability in India [2].

Item	Value	Date reported
Total installed capacity (GW)	209	October 2012
Available base load supply (MU)	893371	October 2012
Available peak load supply (GW)	125.23	October 2012
Demand base load (MU)	985317	October 2012
Demand peak load (GW)	140.9	October 2012

simply unavailable. India is densely populated and has high solar insolation, an ideal place for generating electricity from solar energy. Because of its location between the Tropic of Cancer and the Equator, India has an average annual temperature ranging from 25 °C to 27.5 °C. This means that India has huge solar potential. The sunniest parts are situated in the south/east coast, from Calcutta to Madras. India receives a solar energy equivalent of more than 5000 trillion kWh per year, which is far more than its total annual consumption [25]. The daily global radiation is around 5 kW h per square meter per day with sunshine ranging between 2300 and 3200 h per year in most parts of India. Global solar radiation data map of India is illustrated in Fig. 1. Though the energy density is low and the availability is not continuous, it has now become possible to harness this abundantly available energy very reliably for many purposes by converting it to usable heat or through direct generation of electricity. For example even assuming 10% conversion efficiency of PV modules, it will still be thousand times greater than the likely electricity demand in India by the year 2015 [10].

According to a report of 2011 by BRIDGE TO INDIA and GTM Research, India is facing a perfect storm of factors that will drive solar photovoltaic (PV) adoption at a “furious pace over the next 5 yr and beyond”. The falling prices of PV panels, not only from China but also from the U.S., have coincided with the growing cost of grid power in India [25]. Government support and ample solar resources have also helped to increase solar adoption. The Jawaharlal Nehru National Solar Mission (JNNSM) announced in 2009 is one of the 8 mission's part of the National Action Plan for Climate Change (NAPCC). Interestingly in 2009, the cost of generation from PV Solar was significantly higher (nearly twice, of what it is today). Moreover, the same was also very high as compared to grid power price. Government funded solar energy in India only accounted for approximately 6.4 MW/yr of power as of 2005; 25.1 MW was added in 2010 and 468.3 MW in 2011. In 2012, nearly all the states in India have significantly hiked the power price ranging from 4% to 15% [19].

The state wise solar energy capacities in India in 2013 are listed in Table 2. India installed 240 MW of grid-tied solar photovoltaic (PV) capacity during March 2013, according to the nation's Ministry of New and Renewable Energy (MNRE). India's 2012–2013 year ended on March 31st, 2013; during the year Indian PV capacities nearly doubled, with 754 MW of new capacity installed. PV now represents 6% of all grid-tied renewable energy capacity in the nation [25].

2.2. Grid parity of solar energy in India

Grid parity is the tip at which the cost of generating electricity from alternative energy becomes equal to or less than the cost of purchasing power from the grid. In view of the fact as a result of the condition the exact place of “grid pricing” varies not only from

Table 2
State wise solar energy capacity in India in 2013 [24].

State	MW	%
Andhra Pradesh	23.5	1.6
Chhattisgarh	4.0	0.2
Delhi	2.53	0.1
Gujarat	824	57
Haryana	7.8	0.54
Jharkhand	16	1.11
Karnataka	14	0.97
Madhya Pradesh	11.75	0.81
Maharashtra	34	2.35
West Bengal	2	0.13
Orissa	13.0	0.90
Punjab	9.33	0.6
Rajasthan	442.25	30
Tamil Nadu	17.06	1.17
Uttar Pradesh	12.38	0.86
Uttarakhand	5.05	0.35

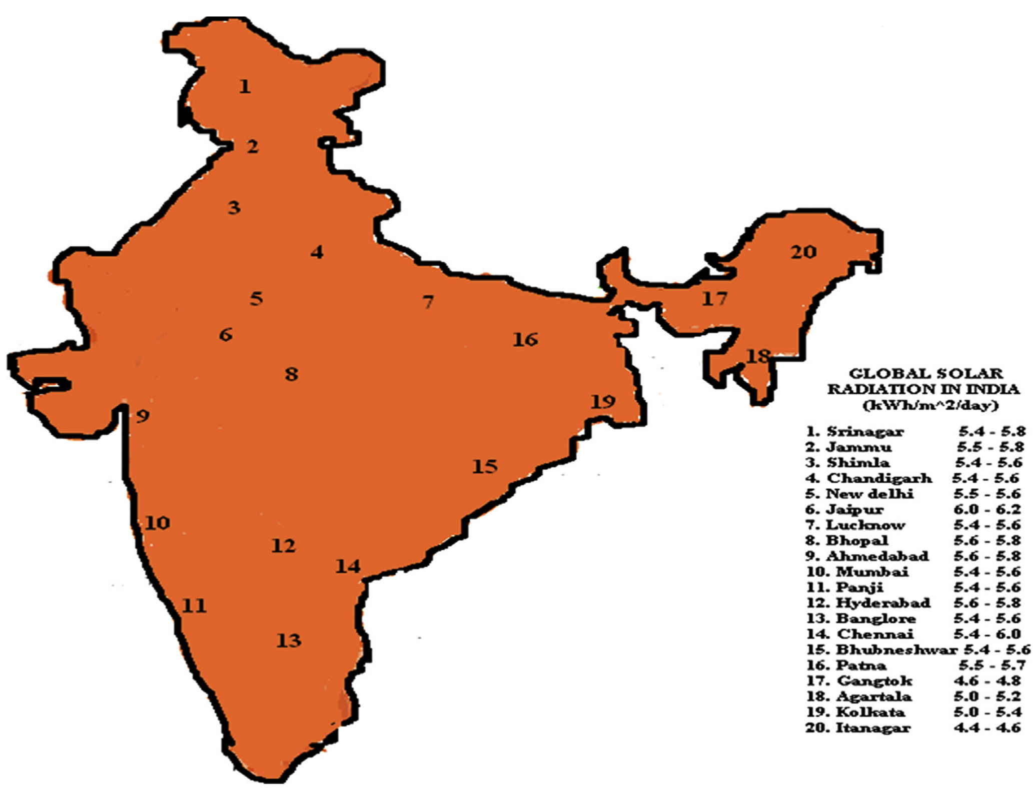

Fig. 1. Global solar radiation in India [30].

site to site but also customer to customer and even hour to hour. Grid parity is very important terminology in the solar system and preferably photovoltaic panel because the capital cost of PV panel is extremely reduced from the year 1990 to 2010. Between late 2009 and mid-2011 it has dropped unpredictably by 70% [21]. Levelised solar power tariffs (INR/kWh) are represented in Table 3. In grid parity, solar energy is compared with natural gas because it is the most expensive form of power. The solar PV industry has seen dynamic changes in the last twelve months. Module prices have seen precipitous fall thereby encouraging forecasts of early grid parity, while at the same time this has raised concern about the health of the manufacturing sector and sustainability of the cost reduction. The National solar mission has triggered the development of solar ecosystem capacity in India in the last two years. India's solar capacity has grown from less than 20 MW to more than 1000 MW in the last two years [10].

We had estimated in our analysis last year that grid parity could happen in the period of 2017–19. The recent trends in the solar power prices indicate that utility scale grid parity could happen at the earlier end of this range [10,21]. Fig. 2 represents comparison of photovoltaic and conventional costs (Rs./unit).

The point at which grid parity occurs is a function of two variables, the rate of increase in conventional power prices and the rate of decrease in solar power prices. We believe the following could be the key trends:

- It is expected that the landed cost of conventional electricity to consumers will increase at a rate of 4% per annum in the base case and 5.5% per annum in an aggressive case. These factors include the increasing proportion of raw material imports, cost of green field generation, and higher investments in network assets to improve operational efficiencies of the utilities.
- Solar power prices are expected to decline at the rate of 5–7% per annum. These factors include the increasing economies of scale in equipment manufacturing and advancements in product technology, which improve solar-to-electricity conversion efficiency [31].

2.3. Challenges and opportunity towards solar energy in India

The Jawaharlal Nehru National Solar Mission (JNNSM), a major initiative of the government of India, has set itself a goal of creating an enabling policy framework for deploying 20 GW of solar power by 2022. The target of the solar system installation is illustrated in Table 4. India's objectives and intentions are commendable. The final output of the recently released policy guidelines reflects both the overarching objectives of developing clean solar power, addressing power shortages and stakeholder concessions. This is the preliminary perspective on the recently released guidelines for new grid-connected solar power projects in India [25,30].

Table 3
Levelised solar power tariffs (INR/kWh) [31,34].

Exchange rate	2012–13	2013–14	2014–15	2015–16	2016–17
Grid connected					
55	8.07	7.59	7.30	6.95	6.55
50	7.53	7.08	6.80	6.47	6.10
Roof top connected					
55	8.69	8.17	7.85	7.46	7.04
50	8.14	7.65	7.34	6.98	6.58

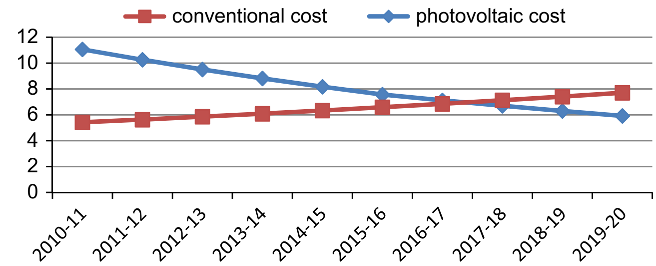

Fig. 2. Photovoltaic and conventional cost per year [10].

2.3.1. Indian power sector challenges

- Country of 600,000 villages – 1/3rd of which does not have access to grid.
- Nearly 600 million Indians do not have access to electricity grid.
- Peak deficit of 12% and energy deficit of 11%.
- One-third of power generated lost before getting used (30% AT & C losses).
- High use of fossil fuel for generation, extensive use of diesel for back up and captive power units, kerosene lamps.
- Per capita energy consumption of 704 kWh.
- Government policy allows 100% FDI (foreign direct investment) in all segments.
- Yet share of power sector in FDI to infrastructure sectors increased only marginally from 16% to 18% over 2006–09. By contrast, FDI to telecommunications is more than 47% [30].

2.3.2. Solar manufacturing challenges

- Dependent on imported wafers for cell manufacturing.
- High cost of financing/capital.
- Competition from China & Taiwan.
- Low demand in India.
- Lack of technical knowledge especially in the upstream segment.

Beyond the above challenges, land is also a scant reserve in India and per capita land availability is low. Dedication of land area for exclusive installation of solar arrays might have to vie with other provisions that require land. The amount of land required for utility-scale solar power plants is currently approximately 1 km^2 for every 20–60 MW (MW) generated [25].

2.3.3. Domestic content and solar manufacturing opportunities

- GOI (Government of India) mandates use of “Made in India” Solar panels for the 1st sub-phase of 150 MW in 2010–11 and Cells & Modules both from 2011–12 onwards.
- 30% domestic content mandate for Solar Thermal Project.
- Various taxation and fiscal incentives for manufacturing in SEZ's
- Currently around 1 GW of module manufacturing and 0.5 GW of cells manufacturing capacity
- The business opportunities for solar energy development in India are significant. India is an interesting example to show the practical possibilities of the development of solar energy in Gujarat and Rajasthan. In particular, India has adequate sunshine, an extended territory free of inhabitants and the “political will” of its government to reach a share of 22% from RES in the national energy balance by 2020.

Table 4
Target of installed solar systems in the years 2012–2022 [30].

Application segments	Target for phase 1 (2012–2013)	Cumulative target for phase 2 (2013–17)	Cumulative target for phase 3 (2017–22)
Grid solar power includes roof top and small solar project	1100 MW	4000 MW	20000 MW
Off-grid solar application includes rural solar lights	200 MW	1000 MW	2000 MW
Solar collector	7 millions square meter	15 millions square meters	20 million square meter

Table 5
India's largest photovoltaic (PV) power plants MW capacity [25].

Name of Plant	Capacity	Notes
Charanka Solar Park – Charanka village, Patan District, Gujarat	214	Commissioned April 2012
Mithapur Solar Power Plant – Mithapur, Gujarat (Tata Power)	25	Commissioned 25 January, 2012
Waa Solar Power Plant – Surendranagar, Gujarat (Madhav Power)	10	Commissioned December 2011
Dhirubhai Ambani Solar Park	40	Commissioned in April 2012
Bitta Solar Power Plant – Bitta, Kutch District, Gujarat (Adani) Power	40	Commissioned January 2012
Mahindra & Mahindra Solar Plant, Jodhpur, Rajasthan	5	Completed in January 2012
Sivaganga Photovoltaic Plant	5	Completed December 2010
Kolar Photovoltaic Plant	3	Completed May 2010
Itnal Photovoltaic Plant, Belgaum	3	Completed April 2010
Chesdin Power – Biomass and Solar Photovoltaic Plants	4.1	Completed December 2011
Citra and Sepset Power Plants – Solar Photovoltaic Plants	4	Commissioned October 2011
Jamuria Photovoltaic Plant [30]	2	August 2009
Tata Power – Mulshi Maharashtra	3	Commissioned April 2011
Azure Power – Sabarkanta, Gujarat (Khadoda village)	10	Commissioned June 2011
Moser Baer – Patan, Gujarat [36] (Precious and Solitaire)	30	Commissioned October 2011
Orissa – Patapur, Orissa	9	August 2012
IIT Bombay – Gwal Pahari, Haryana	3	Commissioned 26 September, 2011
Green Infra Solar Energy Limited – Rajkot, Gujarat	10	Commissioned November 2011

- The JNNSM calls for a total aggregated capacity of 1 GW of grid connected solar projects under the bundling scheme in Phase-I through 2013. Solar PV technology projects and CSP technology projects are to be developed at a ratio of 50:50, in MW terms. This provision is to be reviewed again in one year's time to determine the need for modification. The JNNSM is trying to encourage the development of both PV and CSP technologies by giving each equal weight. However, by allotting specific quotas for each technology, the JNNSM is dictating the ratio of technology that can be built rather than allowing the market to select the most efficient and cost effective technology for India [25,30].

2.4. Government support towards solar energy in India

Renewable energy as one of the current and substantial issues needs to be investigated in terms of political outlook. So the researches on solar energy policies under the energy policies of different countries are necessary. The emergence of renewable energy policy was in the 20th century but it gained momentum in the 21st century [12]. These policies provide significant motivation and interest for the development and use of renewable energy technologies [13]. The government of India has promoted the use of solar energy through various strategies. In the latest budget for 2010/11, the government has announced an allocation of 10 billion (US$189 million) towards the Jawaharlal Nehru National Solar Mission and the establishment of a clean energy fund. It is an increase of 3.8 billion (US$71.8 million) from the previous budget. India's largest PV power plants are listed in Table 5. This new budget has also encouraged private solar companies by reducing customs duty on solar panels by 5% and exempting excise duty on solar photovoltaic panels. It is expected to reduce the cost of a rooftop solar panel installation by 15–20%. The budget also proposed a coal tax of US$1 per metric ton on domestic and imported coal used for power generation. Additionally, the government has initiated a Renewable Energy Certificate (REC) scheme, which is designed to drive investment in low-carbon energy projects [31]. Some important steps are to be taken by the government to promote electricity generation by solar system.

- The government of India through Capital Subsidy Scheme (National Clean Energy Fund) allocated Rs. 46.80 Cr for the installation of solar lighting systems and small capacity PV systems, for the installation of 1,20,000 solar lighting systems for the year 2011–12.
- Imports of solar cells are fully exempted from import tax.
- Generation based incentives (GBI): incentives of Rs. 12.41 per kWh to the state utilities when they directly buy solar power from the project developers. Grid solar power projects in the capacity range of 100 kW–2 MW each, connected to HT grid below 33 KV, are eligible under the scheme.
- 80% accelerated depreciation income tax benefits on renewable energy products (solar lanterns, streetlights, blinkers and traffic signals) if manufactured under specifications laid down by MNRE to avail capital benefits.
- Import duty on raw materials/consumables for manufacturing the solar PV cells and solar PV modules is levied to the tune of 10–15%.
- The Indian government is giving incentives/rebate of Rs. 4000–6000 on purchase of solar water heater [31].

3. Wind power in India

3.1. Overview

Wind energy is the kinetic energy associated with movement of large masses of air. This motion results from uneven heating of

Table 6
State wise comparison of wind power development [29].

	Andhra Pradesh	Gujarat	Karnataka	Madhya Pradesh	Maharashtra	Rajasthan	Tamil Nadu
Annual installation (MW)	54.1	790	206.7	100.5	416.75	545.7	1083
Total number of identified sites	34	40	26	07	33	08	47
Identified number of potential districts	7	9	11	5	12	5	11
Annual mean wind speed (m/sec) @ 50 m height	4.86–6.61	4.33–6.97	5.19–8.37	5–6.25	4.31–6.58	4.02–5.73	4.47–7.32
Number of wind monitoring stations established till July 2012	78	69	59	37	128	36	70
Number of wind monitoring stations operating (as of August 2012)	16	6	12	–	20	1	2
Installable wind potential (MW) @ 80 m height	14497	35071	13593	2931	5961	5050	14152
Presently installed capacity (MW) as on 31st March, 2012	245.5	2966.3	1933.5	376.4	2733.3	2070.7	6987.6
Untapped installable potential (MW) as of April 2012	14251.5	32104	11660	2555	3228	2979	7164

the atmosphere by the sun, creating temperature, density and pressure difference. Wind power is the conversion of wind energy into a useful form of energy, such as using wind turbines to make electrical power, windmills for mechanical power, wind pumps for water pumping or drainage, or sails to propel ships.

Wind energy has been the fastest growing renewable energy sector in the country. Along with good sunshine hours India is blessed with 7517 km of coastline and its territorial waters extend up to 12 nautical miles into the sea. India is the 3rd largest annual wind power market in the world and provides great business opportunities for both domestic and foreign investors. The ministry of Nonconventional energy sources of the Government of India managed and implemented the wind energy program in 1983–84. The development of wind power in India began in the 1990s and has drastically increased in the last few years. The potential in wind has been estimated as 102,778 MW at 80 m height and 49,130 MW at 50 m height at 2% land availability. Wind resource assessment is a continuous process for identification of potential areas for wind farming. There are 220 sites having wind energy density of 200 W/m^2 and above at 50 m height. The total installed wind generation capacity in India as of March 2012 has reached 17,350 MW. The state wise comparison of wind power development is given in Table 6. The gross potential is estimated as 75,000 MW in the potential areas. Wind electric generators of unit sizes between 225 kW and 1.65 MW have been deployed across the country [26,28,29].

India is a prevailing market for the wind industry and Indian wind sector representing annual growth in 2.1GW of new installations. The global wind markets grew by an average 28% per year in terms of total installed capacity during the last decade. According to IEA project India will needed 327 GW power generation capacity in 2020. Wind power would then produce close to 81 TWh every year by 2020 and 174 TWh by 2030 and save 48 million tons of CO_2 in 2020 and 105 million tons in 2030. The wind power investment in India would drop to about 910 million dollars by 2030. Investment in wind power in India would also drop from the current level of € 3.7 billion per year to only € 2.4 billion by 2020 [29].

As many as 20 manufacturers are engaged in the production of wind turbine equipments. A large number of companies have tied up with foreign wind turbine manufacturers for joint venture/licensed production of WECS (Wind energy conversion system) in India. Research and development activities are being undertaken through research institutions, national laboratories, universities and industry for the development of cost effective technologies and systems to improve the quality of power generation from wind. *R* and *D* activities are coordinated through the Centre for Wind Energy Technology (C-WET) [27]. The future of wind energy in India is extremely bright and there is no doubt that in the renewable energy sector, wind power would play a predominant role in adding to the national grid clean and nonpolluting energy to a substantial extent [20].

Table 7
India's cumulative wind power capacity for 2009–2030 [28,29].

Year	Reference [MW]	Moderate [MW]	Advanced [MW]
2009	10926	10926	10926
2010	12276	12629	12833
2015	19026	24747	29151
2020	24026	46104	65181
2030	30526	108079	160741

3.2. *Grid parity of wind energy in India*

Grid parity is also implemented in wind power where it depends on the wind quality and distribution factor. In India predicted wind power's real cost will approach grid parity with coal and natural gas without carbon sequestration and will be much cheaper than natural gas and coal with carbon sequestration by 2022 [22]. Table 7 represents India's cumulative wind power capacity for 2009–2030.

3.3. *Challenges and opportunity for wind energy in India*

Many of the states facing power shortages have sites with good wind power potential that is not being used efficiently and are now saddled with old and inefficient wind turbines; powering with more powerful turbines would bring considerable benefits to these states. One of the primary barriers to this problem is the general lack of economic incentive to replace the older WTGs (Wind turbine generator) [18]. In order to compensate for the additional cost of recovering, some kinds of incentives are a must. Breakdown of critical components badly affects machine availability and O&M cost for smaller capacity machines. The effective capacity utilization reason of small (< 500 kW) machines in Tamil Nadu is estimated at less than 15%. The global market for small wind turbines (SWTs) has been on the upswing over the last two to three years. This is driven by rapidly growing energy demand, higher fossil fuel prices and improved SWT technology, which can be deployed for a diverse pool of applications, both in “grid-tied” and “stand-alone” modes. With the increasing shortage in power supply and energy across the country, India could benefit by exploiting the potential of micro-generation technologies that can meet energy needs under the distributed generation modestly to give long-term solutions.

WISE (World Institute of sustainable energy) estimates India's micro-generation potential at about 83 GW. However, costs are a major hurdle and policy support needs to be oriented toward promoting mass manufacturing and early adoption of these

micro-generation options. Although a small annual market for such systems (150–200 kW) currently exists in India, it is largely driven by the Capital subsidy programmed of the MNRE. Most of the current installations are of the stand-alone type [29]. Fig. 2 represents the cumulative wind power capacity.

3.4. Government support towards wind energy in India

Enactments prior to the Electricity Act, 2003 (EA 2003) had no specific provisions that would promote renewable or nonconventional sources of energy. Despite this shortcoming, the Ministry for New and Renewable Energy25 (MNRE) attempted to give impetus to the sector by way of policy guidelines in 1994–1995, with mixed results. However, the EA 2003 changed the legal and regulatory framework for the renewable energy sector. The Act provides for policy formulation by the Government of India and mandates the State Electricity Regulatory Commissions (SERCs) to take steps to promote renewable and non-conventional sources of energy within their jurisdiction [29].

3.4.1. Generation based incentive (2009–2012)

The Government of India put into effect a Generation Based Incentive (GBI) scheme for grid connected wind power projects in 2009. A GBI of Rs. 0.50 per kWh, with a cap of approximately $33,000 per MW per year, total $138,000 per MW over 10 yr of a project's life is being proposed under this scheme (Figs. 3 and 4).

The main objectives of the GBI scheme are

- facilitating the entry of large Independent Power Producers (IPPs);
- attracting Foreign Direct Investment (FDI) to the wind power sector; and
- to provide a level playing field for various classes of investors.

3.4.2. State wise tariff for wind power

At present SERCs have declared preferential feed-in tariffs (FITs) for purchase of electricity generated from wind power projects. All the SERCs have adopted a “cost plus” methodology to fix the FITs, which varies across the states depending upon the state's resources, project cost and more importantly the tariff regulations of SERCs.

3.4.3. National Clean Energy Fund

The government proposed the creation of the National Clean Energy Fund (NCEF) in the Union Budget 2010–2011 by imposing a clean energy tax (CESS) of INR 50 (∼$1) per ton on all coal produced as well as on coal imports in India [32]. The Ministry of Finance, through the Clean Energy Tex rules 2010, set guidelines for the collection and assessment of this tax by the Revenue

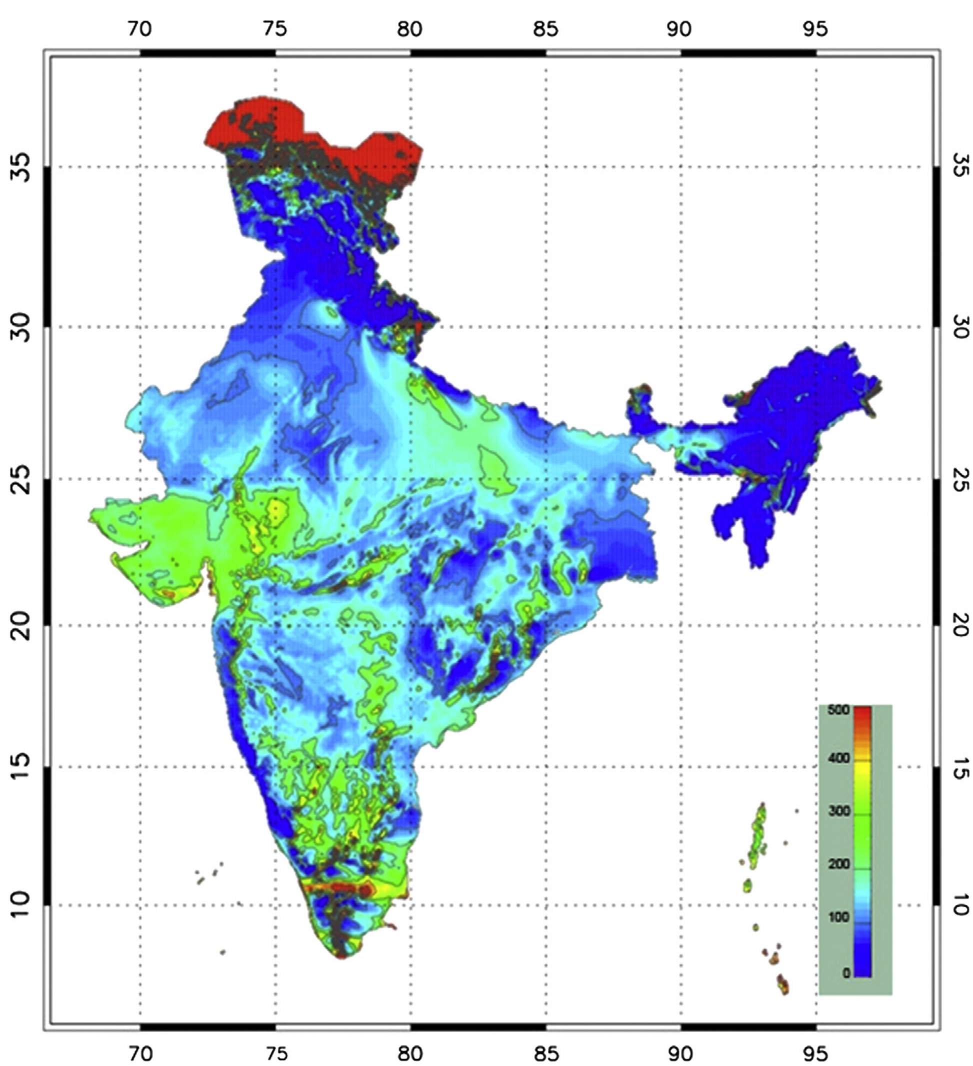

Fig. 3. Wind power density map at 80 m (W/m^2) [29].

Department. Thereafter an inter-ministerial group was set up in the Ministry to approve projects and eligibility requirements for accessing funds from the NCEF31. However, since its inception in July 2010, little information on the operationalization of the NCEF has been released in the public domain other than the guidelines and application form for proposals.

3.4.4. Land allocation policy

In view of the growing number of wind power installations in the country and the increasing scarcity of permissible sites with adequate wind potential the MNRE, through its communication dated 15th May 2012, has requested state governments to examine their land policy for wind power installations and formulate a policy for land allocation on a "footprint" basis. The MNRE is working towards implementing the best practices in this regard [29]. Table 8 represents India's largest wind power production facilities.

4. Obstacle towards solar wind renewable energy development in India

In India electricity is mostly generated from coal based thermal power despite the fact that the stock of coal is likely to last till 2050 and CO_2 emission is contributing alarmingly to global warming and health hazards in the society [15]. Renewable energy programs are especially designed to meet the growing energy needs in the rural areas for promoting decentralized and hybrid development so as to stem growing migration of rural population to urban areas in search of better living conditions [23]. India has a vast supply of renewable energy resources, and it has one of the largest programs in the world for deploying renewable energy based products and systems [16]. The barriers to development of RE in India, in general, are described below. Some of these may be specific to a technology, while some may be specific to a policy, site or a region [19].

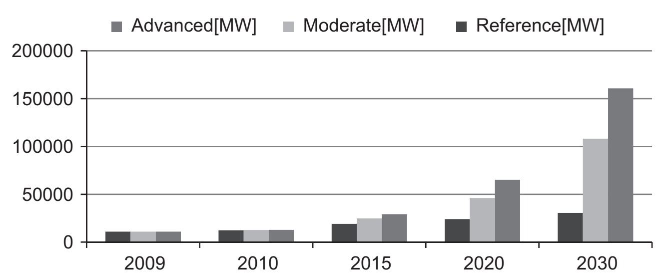

Fig. 4. Cumulative wind power capacity for 2009–2030 [28].

4.1. Policy and regulatory barriers

There is no single comprehensive policy statement for RE in the country. Policies have been issued as and when necessary to facilitate the growth of specific RETs. Further, the plans for development of RE do not match up to these policies. The policy framework at the state level is no better. In fact, in many states policies have only created uncertainty for investments in RE. For example, in Madhya Pradesh, the policy for promotion of non-conventional energy sources waives wheeling charges as well as cross subsidy surcharge for RE. The state government would provide subsidy to the distribution utilities towards wheeling charges @ 4% of the energy injected at the rate of prevailing energy charges to the user for encouraging RE. The policy also exempts wind energy from the payment of electricity duty for a period of 5 yr from COD (Centre for organization development) provided actual generation is at least 70% of the energy generation declared in the DPR. However, the policy is applicable only for a period of 5 yr. Therefore, there is a high degree of policy and regulatory uncertainty for investment in RE [19].

4.2. Institutional barriers

Lack of coordination and cooperation within and between various ministries, agencies, institutes and other stakeholders delays and restricts the progress in RE development. IREDA started accepting applications from wind projects under the GBI scheme soon after the announcement of this scheme. However, the GOI (Government of India) has rejected applications that were made before the notification of the scheme through the gazette and is considering only applications made after such notification. While this justification may hold ground in principle, in practice IREDA should not have started accepted applications before the notification through gazette. Such gaps in implementation of policies because of absence of inter-institutional coordination reduce the faith of investors in the investment climate for RE. Several states have adopted a single window project approval and clearance system for RE. These include Punjab, Himachal Pradesh, Haryana, Rajasthan and Uttarakhand. However, the effectiveness of this

Table 8
India's largest wind power production facilities (10 MW and greater) [6].

Power Plant	Producer	State	Capacity (MW)
Vankusawade Wind Park	Suzlon Energy Ltd.	Maharashtra	259
Cape Comorin	Aban Loyd Chiles Offshore Ltd.	Tamil Nadu	33
Kayathar Subhash	Subhash Ltd.	Tamil Nadu	30
Ramakkalmedu	Subhash Ltd.	Kerala	25
Muppandal Wind	Muppandal Wind Farm	Tamil Nadu	22
Gudimangalam	Gudimangalam Wind Farm	Tamil Nadu	21
Puthlur RCI	Wescare (India) Ltd.	Andhra Pradesh	20
Lamda Danida	Danida India Ltd.	Gujarat	15
Chennai Mohan	Mohan Breweries & Distilleries Ltd.	Tamil Nadu	15
Jamgudrani MP	MP Windfarms Ltd.	Madhya Pradesh	14
Jogmatti BSES	BSES Ltd.	Karnataka	14
Perungudi Newam	Newam Power Company Ltd.	Tamil Nadu	12
Kethanur Wind Farm	Kethanur Wind Farm	Tamil Nadu	11
Hyderabad APSRTC	Andhra Pradesh State Road Transport Corporation.	Andhra Pradesh	10
Muppandal Madras	Madras Cements Ltd.	Tamil Nadu	10
Shah Gajendragarh	MMTCL	Karnataka	15
Shah Gajendragarh	Sanjay D. Ghodawat	Karnataka	10.8
Acciona Tuppadahalli	Tuppadahalli Energy India Private Limited	Karnataka	56.1
Poolavadi Chettinad	Chettinad Cement Corp. Ltd.	Tamil Nadu	10

system is questionable. The issue is sometimes complicated by the fact that delays in obtaining clearances for projects awarded through competitive bidding (such as SHP) result in the levy of a penalty on the developer [19].

4.3. Fiscal and financial barriers

4.3.1. Budgetary constraints

The GOI has announced BGI for wind, roof top PV and for solar power plants that do not qualify under the JNNSM and sell to the state utilities. However, the extent of fund allocation towards payment of such GBI remains to be seen. The budget for FY 2010–11 is awaited in this regard and would be an indicator of GOI's seriousness to this end.

4.3.2. Financing of RE projects

RE projects tend to have little or no fuel costs and, low operation and maintenance (O&M) costs but their initial unit capital costs tend to be much higher than fossil generation systems. The higher ratios of capital cost to O&M cost are significant because they indicate that these projects carry a disproportionately heavy initial burden that must be financed over the life of the project. This makes exposure to risk a long-term challenge (which also has policy and regulatory-risk implications) [11].

- The risk of non-provision of subsidies because of limited or non-availability of resources with the government is also significant since these subsidies may be the lifeline of the project.
- The generally smaller nature of RE projects results in lower gross returns, even though the rate of return may be well within market standards of what is considered an attractive investment [29].

4.3.3. Market-related barriers

The market for RE projects/products in India can be classified into four segments:

- Government market: where the government buys the output of the projects as a consumer, often providing budgetary support for it.
- Government driven market: where the government pursues the use of RE in establishments outside its control for social reasons, often providing budgetary support or fiscal incentives for the same. For example, the government promotes the use of solar applications in schools, malls and hospitals.
- Loan market: where people take loans to finance RE based applications since self-financing is limited.
- Cash market: where High Net worth Individuals (HNI) can buy RE based applications for meeting personal energy needs.

India is currently at an initial stage of the first two segments. The GOI is not focusing on promoting the third and fourth categories of RE, which may offer high potential for RE based applications.

4.4. Technological barriers

4.4.1. Technology risk

In case of many new RETs such as solar thermal, the risks related to technology are high. Since the technology is at a developmental stage, the risks remaining are not clearly known. Further, even though the technology may have been deployed elsewhere in the work, the expected performance of such technology under Indian conditions is not known. Moreover, the risk of technology obsolescence is high.

4.4.2. R&D and manufacturing capabilities

One of the biggest problems confronting RETs such as solar is the high upfront cost of establishing a solar plant. Investments in R&D with the objective of cost reduction and scaling up of operations to utilize economies of scale have long been advocated as the solutions to these problems. Around the world companies and government backed research projects are engaged in advanced R&D and are continuously setting up bigger, more advanced manufacturing facilities. In India, however, manufacturing facilities are only focused on replicating the existing technologies and are limited to small processing units.

4.5. Recommendations

4.5.1. Policy

The GOI must formulate a comprehensive policy or action plan for all-round development of the sector, encompassing all the key aspects. The action plan should be prepared in consultation with the State Governments. It is understood that the Energy Coordination Committee of GOI has approved the preparation of an umbrella RE law to provide a comprehensive legislative framework for all types of RETs, their usage and promotion. However, the GOI has fixed no timeframe for the formulation and enactment of such a law [17]. The GOI must speed up this task and ensure that the desired law be enacted expeditiously. The commercial success of RETs depends significantly on adoption and enforcement of appropriate standards and codes. The GOI must prescribe minimum performance standards in terms of durability, reliability, and performance for different RETs to ensure greater market penetration [19].

4.5.2. Transmission requirements

Grid connectivity to RE generation should be provided by STUs through their capex plans that are approved by the SERCs. Transmission system plans prepared by STUs should cover evacuation and transmission infrastructure requirements for RE sources.

4.5.3. Financing of RE

In order to increase the availability of funds for RE projects, the GOI may consider mandating insurance companies and provident funds to invest 10% of their portfolio into RE. Such investments, in fact, make business sense for the insurance companies. RE, given its benefits, will cause less damage to the environment and human health thereby implying a lower risk of insurance payouts for these companies [33].

4.5.4. Manufacturing

To achieve low cost manufacturing and therefore lower capital costs, and to capitalize on its inherent advantages in the solar sector, India needs to consider revamping and upgrading its solar R&D and manufacturing capabilities. In this regard, the GOI may consider promoting a core company to produce wafer and silicon. This will enable substantial reduction in the costs of solar technologies.

Given the continuing high capital costs of even the commercially deployed RETs despite increasing capacity, there is an urgent need to encourage price reduced capital cost manufacturing through policy [19].

5. Organizations for potential collaboration for renewable energy

The following is a selected list of potential national and state level organizations that may be important to engage in any large scale deployment of renewable energy in India. This list includes existing organizations that play a role in supporting renewable energy development in India currently and may be interested in future collaboration, such as government agencies and organizations, financial institutions, science & technology groups, nongovernmental organizations, and public/private utilities.

- Ministry of Power, Ministry of New and Renewable Energy, and State Renewable Energy Development Agencies.
- MNRE Solar Energy Centre and Centre for Wind Energy Technology (CWET). Indian Renewable Energy Development Agency (IREDA).
- Central Electric Regulatory Commission (CERC) and State Electric Regulatory Commissions.
- Nongovernmental organizations such as World Institute of Sustainable Energy (WISE), The Energy Research Institute (TERI), Center for Science Energy 56 Technology and Policy (CSTEP), and Prayas Initiatives in Health, Energy, Learning and Parenthood.
- Financial institutions, such as ICICI Bank, Yes Bank, and Infrastructure Development Finance Company (IDFC), as well as development financial organizations such as World Bank.
- Educational institutions, such as Indian Institute of Technology (IIT).
- Electric utilities, including NTPC and state electric utilities.
- Trade associations and renewable energy industry members, such as Indian Wind Energy Association.

6. Conclusion

In this review we studied both actual and provisional scenarios for renewable energy in India. The above discussion shows that condition of renewable energy sources such as solar and wind system is satisfactory in India but requires additional attention for better development of renewable energy sources. Although the cost reduction and technological development of renewable energy systems in recent years has been encouraging, they still remain an expensive source of power. To allow the widespread application of this emerging technology, there is a need for further R&D improvements in solar PV and wind technologies that can reduce the cost of renewable system. According to the above discussion India reaches “Grid Parity” in solar energy in 2017 and in wind energy in 2022. For further development it is necessary to focus on a specific technological system which requires better policy measurement and requires more effort of the government in that way.

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